A/N 14487 Reprints WJG

Paper presented at the *First International Symposium on Endangered Species Used in Traditional East Asian Medicine:* ***Substitutes for Tiger Bone and Musk***, Hong Kong, 7-8 December 1997

Musk deer: little understood, even its scent

Michael J.B. Green[1] and Bijaya Kattel[2]

ABSTRACT

The musk deer, genus *Moschus*, is distributed sporadically throughout the forested, mountainous parts of Asia, from just north of the Arctic circle south as far as the Hindu Kusk-Himalayan region of Afghanistan, Pakistan and India. Its taxonomy is unresolved, there being at least four and possibly as many as six species recognised.

The animal is renowned for its musk, a secretion of the male preputial gland which has been used in traditional medicines and in perfumery from as far back as 3,500 BC. Today musk is among the most valuable animal products in the world, worth up to US $ 45,000 or 3-4 times its weight in gold.

Widespread and intense illicit hunting of the musk deer to meet the international demand for musk, combined with habitat destruction, have lead to a drastic decline in musk deer populations. This century populations have disappeared from former parts of their distribution and elsewhere they have become extremely fragmented. That the musk deer has not been wiped out from much more of its geographic distribution can be attributed, in part, to its behaviour: it is essentially solitary and often nocturnal, extremely furtive, and females are likely to be able to reproduce in their first year.

However, much of the musk deer's behaviour, physiology and ecology remain poorly understood, exemplified by the difficulties experienced in maintaining breeding populations in captivity. Ironically, perhaps least understood is the precise role of musk in the animal's behaviour and ecology.

The conservation of the musk deer is discussed, alongside existing constraints in promoting the sustainable production of musk. Future options are considered.

[1] World Conservation Monitoring Centre, 219 Huntingdon Road, Cambridge, UK
[2] Colorado State University, Fort Collins, Colorado, USA

1. INTRODUCTION

The musk deer is best known for its musk, a secretion of the male preputial gland that has been used in traditional oriental medicines and perfumes for many hundreds of years. Such has been the commercial demand for musk, among the most valuable of natural products in the world, that the musk deer has disappeared from many parts of its former distribution.

Despite its renown, little is understood about this small, primitive, deer-like animal. Its evolutionary history remains uncertain, its taxonomy is confused, and its behaviour and ecology are only beginning to be unfathomed. The purpose of this paper is to provide an account of what is known about the musk deer as a basis for considering its future conservation.

2. EVOLUTIONARY HISTORY AND TAXONOMY

2.1 Evolution

The musk deer, *Moschus*, has often been classified as a member of the deer family or Cervidae (e.g. Flower, 1975; Simpson, 1945). Although *Moschus* superficially resembles living deer, a number of other authors have suggested that the genus should be placed in its own family, the Moschidae (e.g. Gray, 1821; Brooke, 1878; Flerov, 1952; Groves and Grubb, 1987; Scott and Janis, 1987). The inclusion of *Moschus* and similar fossil types in a separate family is based on them all retaining primitive ruminant characteristics such as a small to medium body size, large upper canines (tusks) in the males and the absence of antlers, horns or other cranial appendages. Unlike the chevrotains (mouse deer) in the family Tragulidae, however, the tusks are more specialised, the metacarpals are fused and the stomach is four-chambered (Scott and Janis, 1987).

The relationship of the moschids to other pecorans (ruminants with four-chambered stomachs) is less certain. Scott and Janis (1987) place the Moschidae at the base of the superfamily Cervoidae, as the sister group to the Antilocapridae (goat antelopes) and Cervidae (Figure 1.). However, there remains uncertainty about relating the Cervidae more closely to the Antilocapridae than to the Moschidae, based on a number of skeletal features.

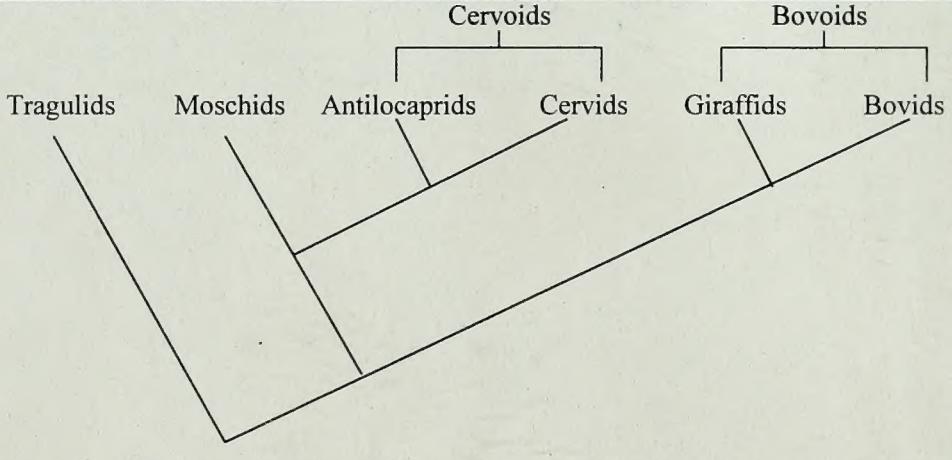

Figure 1 Phylogenetic relationship between living families of ruminants (after Scott and Janis, 1987).

2.2 Taxonomy

Taxonomy of the genus *Moschus* is unresolved, particularly at subspecies level, but there are now considered to be at least four and possibly as many as six species (Groves and Grubb, 1987). For purposes of this paper, the following four species are distinguished:

- forest musk (*M. berezovskii*) in China, Vietnam
- Himalayan musk deer (*M. chrysogaster*) in Afghanistan, China, India, Nepal, Pakistan
- black musk deer (*M. fuscus*) in Bhutan, China, India, Myanmar, Nepal [Note: This is considered by some authorities to be a subspecies of *M. chrysogaster*.]
- Siberian or taiga musk deer (*M. moschiferus*) in China, Korea, Mongolia, former USSR.

Until such time as adequate samples of specimens are examined morphologically, and perhaps genetically, from representative parts of the musk deer's distribution, the taxonomy will remain uncertain (see also Gao, 1985)

3. DISTRIBUTION AND STATUS

3.1 Past and present distribution

In general, the musk deer is distributed sporadically throughout the forested, mountainous parts of Asia, from just north of the Arctic circle south to the northern edge of Mongolia and to Korea. Further south, but avoiding the Gobi Desert, it occurs in China, northern Vietnam, Myanmar and the Hindu Kush-Himalayan region of Afghanistan, Pakistan and India (Flerov, 1930, 1952; Dao, 1977). During the course of this century, this distribution has become fragmented and in some parts contracted.

The forest musk deer, *M. berezovskii*, occurs in the following provinces of southern China: southern Shaanxi, southern Anhui, Hunan, Hubei, Guangdong, Guangxi, Yunnan, Guinzhou, Sichuan, southern Gansu, south-east Qinghai and southern Ningxia. Its distribution extends into northern Myanmar and northern Vietnam. Five subspecies are recognised by Wang *et al.* (1993).

The distribution of the alpine musk deer, *M. chrysogaster* [= *sifanicus*], encompasses Afghanistan, northern Pakistan, northern India, and central China (Grubb, 1982). What is commonly referred to as the Himalayan musk deer is considered to be a subspecies of *M. chrysogaster* whose distribution extends north of the Himalayan divide into Tibet and south-east Qinghai. The overall distribution of the Himalayan musk deer south of the Himalayan divide has changed little during the 20th century but widespread hunting and extensive habitat destruction has reduced the population to isolated fragments in many regions. This population was estimated at 30,000 animals, based on the extent of suitable habitat and the impact of hunting (Green, 1986).

The black musk deer, *M. fuscus*, occurs in north-western Yunnan (above 3,200m), where its distribution partly overlaps with that of *M. berezovskii* (Li, 1981), and the south-eastern corner of Tibet, China (Li, 1981; Ohtaishi and Gao, 1990). It also occurs in Myanmar and Assam, India. An undescribed subspecies is found in the Everest region of Nepal, India (Sikkim) and Bhutan.

The Siberian musk deer, *M. moschiferus*, is found in the former USSR (Siberia and Sakhalin Island), northern Mongolia, China (northern Inner Mongolia, Heilongjiang and Jilin) and Korea. It has disappeared from Sinkiang, Shanxi, Hebei and Shaanxi (Bannikov *et al.*, 1980; Ohtaishi and Gao, 1990).

Further details about the species' known distributions within each country are summarised in Annex 1.

3.2 Reasons for decline

Musk deer populations have declined dramatically during this century as a direct result of widespread illicit hunting of the animal for its musk. Given that a single musk gland or *pod*, weighing on average 25g, will provide a pastoralist family with 6-12 month's cash income (Jackson, 1979; Harris, 1991), hunting is very intense and populations within a given valley may be wiped out within a few years. Hunting, traditionally with snares but increasingly with guns, is largely indiscriminate of the age and sex of animals, such that four or five musk deer may be killed for every pod-bearing male secured (Jackson, 1979; Green, 1986).

Habitat destruction, due to increasing human and livestock populations in many Himalayan and other mountainous regions, is also a serious threat. This applies particularly to the shrub layer of vegetation which provides musk deer with food and camouflage from predators, including man. Expanding pastoralism may also affect musk deer indirectly through predation and harassment by domestic dogs, used to protect livestock (Green, 1986; Harris, 1991).

3.3 Musk trade

Musk is used in perfumery, both for its fixative and scent properties, and in oriental medicines. It was used in China and India as far back as 3,500 BC, and by the 7th Century AD it was traded with the Arabs (Genders, 1972). Relatively little is used in perfumery nowadays, due to its increasing scarcity and high cost, and commensurate replacement by much cheaper synthetic alternatives. Most musk is used in traditional Chinese, Hindu (*ayurvedic*) and Moslem (*unani*) medicines for its alleged cardiac, circulatory, respiratory and sexual stimulant properties, as well as a sedative for nervous disorders (Pereira, 1857; Mukerji, 1953; Anon., 1979).

Musk is among the most valuable animal products in the world, worth 3-4 times its weight in gold. In the 1970s, its international market value was up to US $ 45,000 per kg. At that time, Japan was the largest importer of musk, accounting for some 85% (275 kg) of the international trade (Green, 1986). In the early 1980s, total annual musk production in China was 2,000-2,500 kg, of which 500 kg originated from *M. berezovskii* (Wang *et al.*, 1993). In the Russian Altai, 50 kg was officially traded in 1990-91, thought to represent about 10,000-20,000 musk deer, *M. moschiferus* (Prikhod'ko, 1987).

Current levels of the international trade have not been documented, but there is no reason to expect them to have declined, given that musk deer continue to be hunted and populations continue to decrease throughout much of their geographical distribution.

3.4 Conservation status

International level

According to the IUCN criteria for threatened species, *M. moschiferus* is listed as a vulnerable species in view of its declining populations. The other three species are considered to be at lower risk (near threatened); in other words, they almost qualify as vulnerable species.

Commercial trade in musk (or any other derivatives of the musk deer) is restricted under the Convention on International Trade in Endangered Species of Wild Fauna and Flora (CITES). Populations of *Moschus* species from. Afghanistan, Bhutan, India, Myanmar, Nepal and Pakistan are listed under Appendix I of CITES, thereby prohibiting any import of animals or parts thereof for primarily commercial purposes. All other populations of *Moschus* are listed under Appendix, which means that musk from these populations may be traded subject to strict regulation

National level

The musk deer is severely threatened within some countries. Although it is protected under national legislation in many range states, effective protection is minimal due to inadequate resources, even within many of the protected areas in which the species occur. The population is arguably best protected in Bhutan, where poachers are deterred in the knowledge that they may legitimately be shot on sight. Details of national legislative provisions for musk deer are summarised in Annex 2.

4. BEHAVIOUR AND ECOLOGY

4.1 Habitat preference

Musk deer inhabit montane forests and subalpine scrub throughout much of their distribution. Dense undergrowth, typically of rhododendron, bamboo and other shrubs, is a prerequisite, with a marked preference for steep slopes (Bannikov *et al.*, 1980; Green, 1987a; Kattel, 1992)

Use of habitat may vary with activity, time of day and season in response to the availability of cover, food, shelter and other variables. In Kedarnath, N. India, musk deer were found to be most active at night, feeding in more exposed habitats, such as alpine meadows, under the cover of darkness (Green, 1985, 1987a). In Sagarmatha, Nepal, most use of birch-rhododendron forest and dwarf rhododendron scrub is made in winter, probably because of the greater availability of food (arboreal lichens in particular) in these habitats during this season (Kattel, 1992).

4.2 Food requirements

Musk deer are concentrate feeders, selecting easily digestible, nutritious foods that are high in protein and energy (sugars) and low in fibre (Green, 1987b; Kattel, 1992). In Kedarnath, N. India, forbs and woody plants constitute the bulk of the diet in summer and winter, respectively (Green, 1987b). During winter, when food is in short supply, musk deer survive on poorer quality diets. Where available, musk deer may switch to feeding largely on arboreal lichens (*Usnea* spp.), which are low in protein but high in energy that is easily fermentable and readily absorbed during digestion (Kattel, 1992). Evergreen foliage, such as *Rhododendron campanulatum* (Green, 1987b), and arboreal lichens may be the only readily available food plants during winter when the snow may be one metre deep. Musk deer are also able to jump into trees for feeding purposes (Kattel, 1992; H. D. Xu, pers. Comm., 1997). As winter progresses and

snow becomes deeper, so foliage and arboreal lichens become accessible from increasingly higher levels within trees and shrubs.

Feeding in winter is aided by the musk deer's adaptation to moving in snow. It's dew claws are enlarged, helping to spread its body weight over a larger surface area, thereby minimising sinking in soft snow and maximising its competitive advantage over similarly sized ungulates. The ratio of body weight to hoof area is estimated to be 83.6g km^{-2} (Kattel, 1992), which is lower than for any other ungulate. In practice, measurements show that the maximum depth to which musk deer sink in snow is 26 cm, and on average it is only half this value (Green, 1985).

4.3 Ranging behaviour

Musk deer are essentially sedentary, with home ranges of 13-22 ha recorded for populations in North India, Nepal and the Tibetan Plateau (Green, 1985; Kattel, 1992; Harris and Cai, in press). Studies of these populations show no evidence of any seasonal movement to lower altitudes with the onset of winter. As already discussed, they are well-adapted to moving through deep, soft snow; moreover, they are well protected from the cold by their thick coat of hairs that are crenellated and constructed of air-filled cells to maximise insulation (Green, 1985). In some parts of Russia, however, musk deer may migrate up to 35km in winter as a result of food supplies and shelter becoming covered by snow (Bannikov *et al.*, 1980).

Males tolerate females within their home ranges but not other males, from whom they defend their territories. However, home ranges of females may overlap each other. In Sagarmatha, Nepal, where population density is high (23 musk deer recorded within 50ha), the home range of one male overlapped with parts of the home ranges of five females. Moreover, the home ranges of these five females partially overlapped with those of several of the other females (Kattel, 1992). Similar patterns were evident in Kedarnath, N. India, where the winter homes of a male and female overlapped considerably, but those of two adjacent males did not overlap with each other (Green, 1985, 1987c). A much lower population density of 5-6 musk deer km^{-2} in Kedarnath, probably reflecting reduced food availability and possibly past hunting practices, may account for the lower incidence of overlapping home ranges.

4.4 Social behaviour

Direct and indirect observations, using radiotelemetry, indicate that musk deer are solitary animals, spending most of their time alone. In Kedarnath, N. India, musk deer were only once observed together during 151 observations and a total observation period exceeding 63 hours spread over a three year study period (Green, 1985, 1987a). In Sagarmatha, Nepal, adult females were sometimes seen with young in late summer, and adult females and males were commonly seen together during the rut (Kattel, 1992). Such differences between these two study populations may reflect differences in population density.

Solitary behaviour is typical of small, forest ruminants which rely chiefly on olfaction for communication. Visual contact is impaired by the dense nature of the forest or scrub habitat. Moreover, vocalisation, as a means of long-range communication, is presumed to be incompatible with an anti-predator strategy that relies on remaining inconspicuous.

Chemical signals are strongly developed in the musk deer. Droppings, urine, and in

the case of males, secretions from the musk, caudal and interdigital glands, are used as scent-marks (Green, 1987c). Nothing is known about the interdigital gland, except that it is found in the front feet of the male (Pocock, 1910), so it will not be considered further here.

Droppings

Musk deer, both sexes, use latrines for purposes of defaecation. Peak use of latrines is in December, coinciding with the estimated peak of the rut (Green, 1987c). In the Himalaya, the rut usually coincides with the driest time of year. In order to keep their pellets moist and smelly during the dry autumn season, musk deer often cover them with earth, old pellets, leaf litter and any other available debris (Green, 1987c).

Latrines are distributed throughout the home range. There is circumstantial evidence, based on measurements of pellet weights, that the extent to which latrines are shared by individuals corresponds with the degree of overlap between animals' ranges. Thus, rather than serving as boundary markers, latrines are communication centres providing information on the identification, whereabouts and perhaps even reproductive condition of the occupant(s) of a particular range or set of overlapping home ranges (Green, 1987c).

Urination and musk secretion

The role of musk in the life of a musk deer is far from understood. The musk gland lies in the preputial region, opening via a duct just a few millimetres anterior to the urethral opening. A gland measures 4-6cm long, 3.5-4.5cm wide and 4cm in depth.

There is preliminary evidence that musk is conveyed in the urine of males, based on observations in winter of snow often being stained pink or red from the urine of males, rather than amber as in the case of female musk deer and other ungulates. Also, snow stained with the urine of males is usually sweetly scented (Green, 1987c). Given the close proximity of the opening of the musk gland anterior to that of the urethra, it is likely that either the musk is squirted into the urine stream by contraction of the striated muscles of the musk gland, or the stream of urine is directed to pass over the musk-coated hairs covering the aperture of the gland. Whether musk is used to scent the body, as well as the urine, is not known. In the event of the former, urine may be used to disperse the scent over the body.

Pasting with the caudal gland

The caudal gland of the male occurs as a thickening at the base of the short (c. 2.5cm) tail. A viscous yellow secretion, having an offensive odour that is not at all musky, exudes from a pore on either side of the tail (Hodgson, 1841). The tail is naked, except for a terminal tuft, owing to the frequent act of rubbing its glandular base against objects.

Typically, male musk deer rub the base of their tale against the stems of bushes or dried herbs and grasses. The only detailed study of such pasting behaviour has shown that male musk deer mark in this way throughout their home ranges, both in captivity and in the wild. However, 70% of paste marks were concentrated in a broad peripheral belt, inside of which were distributed most latrines (Sokolov and Prikhod'ko, 1979). This pattern of scent marking is open to various interpretations, but clearly the use of faeces to mark home ranges may be subject to more severe production constraints than that of caudal gland secretions.

Functions of scent-marking

The functions of scent-marking in the musk deer remain poorly understood. Territory marking may provide intruders with a means of identifying residents by their scent, which is matched during agonistic encounters with the memorized scent of marks encountered in the immediate vicinity. Thus, scent marks enable an intruder to assess the quality of a potential competitor, thereby avoiding an escalation in agonistic encounters. Similar processes of recognition by scent-matching may be involved in mate choice, enabling females to select mates that are successful in competing with others. It follows, therefore, that a high frequency of scent-marking would be advantageous to a male if it helped, through dominance over male intruders, to maintain exclusive access to one or more females. The seasonal use of latrines and, in males, the seasonal synthesis of musk in summer for use later in the year to scent the urine may confer similar benefits. The chemical signals may be important for determining access not only to females but also to other resources in short supply, given that such behaviour continues beyond the rut for much of the winter (Green, 1987c).

4.5 Reproduction

Musk deer breed seasonally. The rut occurs between November and early January, and the young are born in May-June after a gestation of 178-198 days. There appears to be a trend of increasing length of gestation with increasing size of species: *M. berezovskii*, the smallest species, has the shortest gestation; *M. chrysogaster*, the largest species, has the longest; and *M. moschiferus* occupies an intermediate position with respect to both its size and gestation period (Green, 1989).

Litter size varies between one and three. The incidence of twins is higher than single births in *M. berezovskii* and *M. moschiferus*; conversely, single births are predominant in *M. chrysogaster* (Green, 1989). Whether such differences are species-specific or governed by environmental conditions is uncertain. Young grow rapidly, becoming independent of their mothers by about six weeks. They attain most of their adult body weight by six months and sexual maturity by 18 months of age. Females are capable of breeding in their first year (Green, 1987a, 1989). In captivity, musk deer have been known to live up to 20 years (Zhang, 1983).

5. MUSK PRODUCTION

Males secrete musk from an age of 12-18 months onwards. Peak production of musk, marked by the visible swelling of the musk gland and scrotum, occurs in May-July prior to the autumn rut. This condition lasts for several weeks during which yellow, milky musk drains via ducts into the neck of the musk gland. Here, over a period of 30 days or more, it is mixed with slough from the inner wall of the gland and matures into a powerfully scented, granular, red-brown substance (Campbell, 1837; Zhang *et al.*, 1979; Bi *et al.*, 1980). The synthesis of musk is negligible in castrated males, suggesting that it is regulated by androgens from the testes (Zhang *et al.*, 1979). Most musk is produced from animals between three and eight years of age (Bista *et al.*, 1979). Males in captivity produce little musk by the age of 14 years, but the ability to secrete the substance still persists at 20 years of age (Zhang, 1983).

Traditionally, musk deer are killed to excise the musk gland or *pod* as it is known in the trade. However, musk can be extracted through the external orifice of the musk gland without killing the animal. The Chinese, and others, have been experimenting

with breeding musk deer in captivity for the production of musk since 1958. In China about 18g (10g dry weight) of musk is harvested annually from captive males (Anon., 1974, 1975). This is higher than the mean of 11.6g musk (N=7, range = 7-15g) obtained from animals captured (and released) in the wild in Sagarmatha, Nepal (Kattel, 1992). However, the available data are insufficient to predict the optimum time of year for extraction of musk from wild animals.

5.1 Harvesting musk from captive animals

Existing information on farming musk deer is inadequate for assessing its economic viability. Even with improvements in rearing and breeding musk deer in captivity, there remains the problem of raising males at high densities without resorting to practices that are counter to animal welfare. Furthermore, as musk deer are easily stressed, extraction of musk needs to be performed under anaesthesia unless animals are tame. In reviewing the Chinese experience , it appears that musk deer are difficult to farm intensively and usually captive stocks have to be replenished with animals from the wild (Green, 1989).

During initial attempts by the Chinese to build up captive stocks with musk deer from the wild, the mortality rate was 60-70%, with many animals dying from gastroenteritis primarily as a result of poor husbandry (Bista *et al.*, 1979). Newly captured fawns, which are preferred to adults because they are easier to tame, are particularly prone to such infection unless preventative measures are taken (Zheng, 1980). The other commonly fatal disease, to which young are very susceptible, is pneumonia (Bista *et al.*, 1979).

The musk deer has been a relatively difficult species to breed in captivity. Of 32 recorded births in zoos worldwide between 1959 and 1980, only 17 (53%) survived (Green, 1985). In China, survival of young has improved from 50% to over 90% at Foziling Farm in Anhui (Anon., 1975), and at Ma Er Kang Farm in Sichuan it averaged 74.4% (n = 336) during the period 1959-73 (Anon., 1974).

In Sichuan's state farms, advances in domesticating and breeding musk deer were sufficient for the capture of wild animals to be discontinued after 1965 (Bista *et al.*, 1979). Such progress is not widespread in China, as most captive stocks still need to be replenished with animals from the wild (Green and Taylor, 1986).

The musk deer's solitary habits (Green, 1985) tend to preclude intensive husbandry. Males are probably territorial and cannot be raised together in confined spaces without risk of injury from fighting. The Chinese practice of isolating males in small cages is not only considered inhumane but cannot be conducive to their productivity. Such treatment may be responsible for the reputed inferior quality of musk from farmed animals.

5.2 Harvesting musk from wild animals

The problems and costs of maintaining musk deer in captivity could be avoided by harvesting musk from free-ranging animals on the basis of either capturing live animals, then releasing them after extracting the musk (Green, 1978, 1986), or culling them as was practised in the Soviet Union (Bannikov *et al.*, 1980). Rural development schemes to harvest musk from wild or ranched animals would provide local communities with the motivation to protect not only the musk deer but also its habitat (Green, 1986; Green and Taylor, 1986).

A major constraint to harvesting musk from live animals in the wild is developing a suitable method of capture. Green (1985) tried various techniques (traps and nets) but they all proved to be unsuccessful. More recently, Kattel (1992) developed a technique of driving previously located animals into nets (6m long and 2m high) using a team of 10-12 persons. This proved to be very successful, with a 56% success rate (25 captures out of 45 attempts). Once captured, animals were immobilised for purposes of attaching radiocollars and extracting musk.

Another constraint is the widespread and centuries-old practice of adulteration (Green, 1989). Some simple method of assaying the purity of musk needs to be developed. In Japan, the leading importer of musk measures the muscone content by gas-liquid chromatography, but a less sophisticated technique is needed for ready application in the field.

In view of the highly lucrative nature of the musk trade, commercial operations to harvest musk from captive or wild animals must be accompanied by the proper protection of the musk deer in conservation areas (Green, 1986). At present, wild populations of musk deer are threatened by hunting. The extent to which this is occurring under the cover of farming enterprises in China is not known, but farming provides an infrastructure whereby musk obtained from wild animals can be traded as farmed musk with reduced risk of apprehension.

6. CONSERVATION

6.1 Threatened but not yet extinct

The musk deer is under tremendous threat from hunting and, increasingly, habitat destruction. Given the long history of the musk trade and the very high demand for musk, it is perhaps surprising that populations have not been extirpated from many more parts of their distribution. This can be attributed to various aspects of the animal's behaviour.

The musk deer is a very elusive animal, being mostly solitary and capable of hiding in dense scrub amidst inhospitable terrain. The high level of nocturnal feeding activity in more exposed parts of the home range, as recorded in some populations, is likely to be an adaptive response to hunting, and to disturbance by local people and their livestock. All of these behavioural characteristics make hunting extremely labour intensive, as indicated by the intensity of trapping (100-600 snares km^{-2}) in some remote Himalayan valleys (Green, 1978). It is largely the market price of musk and the ready availability of musk from elsewhere which determines whether or not it is worth hunting populations to extinction.

Another important factor which has undoubtedly contributed to the survival of the musk deer, despite intense hunting, is its high reproductive rate (Green, 1989). Young mature quickly and, although not yet confirmed in wild populations, they are capable of breeding within their first year. Moreover, the incidence of twins and even triplets is quite high in *M. berezovskii* and *M. moschiferus*. Whether or not attainment of sexual maturity and litter size are influenced by hunting pressures remains unstudied.

Conservation measures through the establishment of protected areas are beginning to prove effective, albeit only in a very few cases because of largely inadequate resources to manage them effectively. A good example is Nepal's Annapurna Conservation Area, where wildlife populations including musk deer have recovered

significantly since the launch of the Annapurna Conservation Area Project in 1987 (C. Gurung, pers comm., 1997). However, local culture and traditions have played a much stronger role in protecting some populations of musk deer. For example, musk deer may be strictly protected in the vicinity of certain Buddhist temples (Harris, 1991; Kattel, 1992).

6.2 Future prospects

The musk deer is threatened throughout its distribution but, for reasons discussed in the previous section, it is not yet seriously at risk of becoming extinct. Unlike the tiger, therefore, which participants of the symposium consider likely to become extinct unless strictly protected, there is still a little time in which to develop and implement conservation strategies that include the sustainable production of musk.

While the development of synthetic substitutes for natural musk is necessary to meet the tremendous demand for musk in perfumery and traditional medicines, it is symptomatic of the high price and difficulty of obtaining natural musk that has resulted from the widespread over-exploitation of the musk deer. To attempt to completely replace natural musk with synthetics may be misguided because, arguably, this devalues the musk deer and does not address the root of the problem - a failure by civil societies to adopt sustainable lifestyles. Unlike tiger bone, for which many other animal bones have proved to be effective substitutes, musk is much more extensively used in traditional Chinese medicine, and its replacement by substitutes (synthetics) is not generally accepted. Whereas, the continued use of natural musk in perfumery is a luxury, particularly in the wake of the development of synthetic musks, its use in traditional medicines can be more readily justified provided such musk production is sustainable and humane.

Clearly, there is a challenge ahead to reverse the present over-exploitation of musk deer and an important opportunity to establish musk deer as flagship species which, managed sustainable for their highly valued musk, can help to ensure the protection of fragile mountain environments and the welfare of mountain peoples.

The effective protection of musk deer within protected areas is of paramount importance. This is unlikely to be achieved without the participation of local communities in management processes, particularly since government resources for protected areas in the musk deer's range states are usually grossly inadequate.

In order to engage the cooperation of local communities, clear social and economic benefits must derive from maintaining protected areas. In the case of musk deer, ecotourism offers a potential market which might help to promote the animal's conservation.

Outside strictly protected areas, there is the opportunity to harvest musk from wild or possibly ranched populations. This would be particularly beneficial for local people living at subsistence level in remote mountainous regions, where alternative sources of livelihood are meagre (Green, 1985, 1989). While there are major technical problems to overcome, such as efficient capture and release of free-ranging animals, and checking the purity of musk, the major challenge will be to ensure that legitimate harvesting of musk does not provide cover for animals to be poached from within protected areas. However, with the full involvement of local communities in musk harvesting enterprises and benefits accruing directly to them, their support in policing protected areas from poachers will have been won.

Thus, the biggest challenge is not so much developing substitutes for musk and banning its trade, which ultimately may do little for protecting musk deer in the wild and providing economic benefits to rural communities, but finding technical, social and political solutions to sustainably harvesting musk from wild animals in areas buffering protected areas. This symposium is timely, providing the opportunity for the conservation and traditional Chinese medicines communities to begin working together to conserve the musk deer and its fragile mountain environment, while providing for the wealth and health of rural communities through the sustainable production of musk.

ACKNOWLEDGEMENTS

The authors are very grateful to Jonathan Barzdo for his comments on an earlier version of this paper.

REFERENCES

Anon. (1974). Feeding musk deer in captivity and collecting musk from the live animal. *Dongwuxue Zahzi, China*, 1974(2), 1-14.

Anon. (1975). Preliminary experience in raising the survival rate of musk deer. *Dongwuxue Zahzi, China*, 1975(1), 17-9.

Anon. (1979). *Faunal pharmacopoeia of China.* Tianjin Scientific and Technical Press, Tianjin.

Bannikov, A.G., Ustinov, S. K. and Lobanov, P.N. (1980). The musk deer *Moschus moschiferus* in the USSR. IUCN, Gland, Switzerland. Unpublished manuscript. 46 pp.

Bi, S. Z., Yan, Y. H., Qing, Z. X., Sheng, P. T., Wu, Y. M., Chen, C. F. Xu, H. J., Yang, G. K., Yin, T. B. and Lu, Y. J. (1980). Dissection and analysis of the musk gland of *M. moschiferus* and a preliminary investigation into its histology. *The Protection and Use of Wild Animals, China*, 1, 14-19.

Bista, R. B., Shrestha, J. N. and Kattel, B. (1979). Domestication of the dwarf musk deer (*Moschus berezovskii)* in China. Kathmandu: National Parks and Wildlife Conservation Office. Unpublished Report.

Brooke, V. (1878). On the classification of the Cervidae, with a synopsis of the existing species. *Proceedings of the Zoological Society of London* 1878: 883-928.

Cai, G. Q. and Feng, Z. J. (1981) On the occurrence of the Himalayan musk deer (*Moschus chrysogaster*) in China and an approach to the systematics of the genus Moschus. *Acta Zootaxonomica Sinica* 6: 106-110.

Campbell, A. (1837). Notes taken from the post-mortem examination of a musk deer. *J. Asiat. Soc. Beng.* 6: 118-120.

Dao, V.T. (1977). Sur quelques rares mammiferes au nord du Vietnam. *Mitteilungen-Zoologischen Museum in Berlin* 53: 325-330.

Flerov, C.C. (1930). On the classification and geographical distribution of the genus *Moschus* (Mammalia, Cervidae). *Yearbook of the Zoological Museum of the USSR Academy of Science* 31: 1-20.

Flerov, C.C. (1952). *Fauna of the USSR.* Volume 1. *Mammals: musk deer and deer.* USSR Academy of Sciences, Moscow. Pp. 14-45. (Translated from Russian by Israel Program for Scientific Translations.)

Flower, W. H. (1975). On the structure, and affinities of the musk deer (*Moschus moschiferus*, Linn.). *Proceedings of the Zoological Society of London* 1875: 159-190.

Gao, Y. T. (1985). Classification and distribution of the musk deer (*Moschus*). In: *Contemporary Mammalogy in China and Japan*, ed. T. Kawamichi. Mammalogical Society of Japan. Pp. 113-116.

Genders, R. (1972). *Perfumes through the ages.* G. P. Putman, New York.

Golovanov, V. (Ed.) (1985). *Nature reserves of the USSR: nature reserves of the Far East.* Mysl' Publishing House, Moscow. 317 pp. (In Russian)

Gonzalez, G. (1994). Deer harvest in Sikhote-Alin, Russia. *IUCN Deer Specialist Group Newsletter* 12: 5.

Gray, J. E. (1821). On the natural arrangement of vertebrate mammals. *Lond. Med. Reposit.* 15: 296-310.

Green, M.J.B. (1985). Aspects of the ecology of the Himalayan musk deer. Ph.D. thesis, University of Cambridge, Cambridge. 280 pp.

Green, M.J.B. (1986). The distribution, status and conservation of the Himalayan musk deer (*Moschus chrysogaster*). *Biological Conservation* 35: 347-375.

Green, M.J.B. (1987a). Some ecological aspects of a Himalayan population of musk deer. In *The biology and management of the Cervidae*, ed. C.M. Wemmer. Smithsonian Institution, Washington DC. Pp. 307-319.

Green, M.J.B. (1987b). Diet composition and quality in Himalayan musk deer based on fecal analysis. *Journal of Wildlife Management* 51: 880-892.

Green, M.J.B. (1987c). Scent-marking in the Himalayan musk deer (*Moschus chrysogaster*). *Journal of Zoology, London (B)* 1: 721-737.

Green, M. J. B. (1978). Himalayan musk deer (*Moschus moschiferus moschiferus*). In *Threatened Deer*. IUCN, Morges. Pp. 56-64.

Green, M.J.B. (1989). Musk production from musk deer. In *Wildlife production systems*, eds. R. J. Hudson, K.R. Drew and L.M. Baskin. Cambridge University Press, Cambridge. Pp. 401-409.

Green, M. J. B. and Taylor, R. (1986). The musk connection. *New Scientist*, 110 (1514), 56-8.

Groves, C.P. and Grubb P. (1987). Relationships of living deer. In: *Biology and management of the Cervidae*, ed. C.M. Wemmer. Smithsonian Institution Press, Washington DC. Pp. 21-59.

Grubb, P. (1982). The systematics of Sino-Himalayan musk deer (*Moschus*), with special reference to the species described by B.H. Hodgson. *Sa getierkundliche Mitteilungen* 30: 127-135.

Habibi, K. (1977). *The mammals of Afghanistan: their distribution and status.* UNDP/FAO/Department of Forests and Range, Kabul.

Harris, R.B. (1991). Conservation prospects for musk deer and other wildlife in southern Qinghai, China. *Mountain Research and Development* 11: 353-358.

Harris, R.B. and Cai, G. (in press). Autumn range of musk deer in Baizha Forest, Tibetan Plateau. *Journal of the Bombay Natural History Society.*

Hodgson, B. A. (1841). On a new organ in the genus *Moschus. Journal of the Asiatic Society of Bengal* 10: 795-796.

IUCN (1993). *Nature reserves of the Himalaya and the mountains of Central Asia.* IUCN, Cambridge and Oxford University Press, New Delhi. 471 pp.

Jackson, R. (1979). Aboriginal hunting in West Nepal with reference to musk deer *Moschus moschiferus moschiferus* and snow leopard *Panthera uncia. Biological Conservation* 16: 63-72.

Kattel, B. 1992. Ecology of the Himalayan musk deer in Sagarmatha National Park, Nepal. Ph.D. thesis, Colorado State University, Fort Collins. 76 pp.

Li, Z. X. (1981). On a new species of musk deer from China. *Zool. Res., Kunming*, 2, 157-161.

Mallon, D. P. (1985). The mammals of the Mongolian People's Republic. *Mammal Review* 15: 71-102.

Mukerji, B. (1953). *Indian pharmaceutical codex*. Volume 1. Council of Scientific and Industrial Research, New Delhi. Pp. 149-150.

Ohtaishi, N. and Gao, Y.-t. (1990). A review of the distribution of all species of deer (Tragulidae, Moschidae and Cervidae) in China. *Mammal Review* 20: 125-144.

Pereira, J. (1857). *The elements of materia medica and therapeutics*. Volume 2. 4th edition. Longman, Brown, Green, Longmans and Roberts, London.

Pocock, R. I. (1910). On the specialised cutaneous glands of ruminants. *Proceedings of the Zoological Society of London* 1910: 840-986.

Prikhod'ko, V.J. (1987). Breeding of musk deer (*M. moschiferus* L.) for the production of musk. XVIII Congress of the International Union of Game Biologists, Jagiellonian University, Krakow. Abstracts. Pp. 159-160.

Roberts, T. J. (1977). *The mammals of Pakistan*. London, Ernest Benn.

Scott, K. M. and Janis, C. M. (1987). Phylogenetic relationships of the Cervidae and the case for a superfamily "Cervoidae". In *The biology and management of the Cervidae*, ed. C.M. Wemmer. Smithsonian Institution, Washington DC. Pp. 3-20.

Sheng, H.L. (1987). The prosperity and decline of musk deer resources, and strategies for its recovery. *Chinese Wildlife* 3: 3-4. (In Chinese)

Simpson, G. G. (1945). The principles of classification and a classification of mammals. *Bulletin of the American Museum of Natural History* 85: 1-114.

Sokolov, V. E. and Prikhod'ko, V. I. (1979). Marking of territory by caudal gland of musk deer (*Moschus moschiferus*). *Proceedings of Academy of Science of the U.S.S.R. (Biological Science)* 246: 894-897.

Wang, Y., Ma, S. and Li, C. (1993). The taxonomy, distribution and status of forest musk deer in China. In : *Deer of China: biology and management*, eds. N. Ohtaishi and H. I. Sheng. Elsevier Science Publishers, Amsterdam. Pp. 22-30.

Whitehead, G. K. (1994). *Deer of the world*. London, Constable.

Won, P.O. (1988). Rare and endangered species of mammals in South Korea. *Bulletin of the Institute of Ornithology, Kyung Hee University* II: 61-65.

Yonzon, P.B. (1992). Strategies of wildlife inventory in conserving Bhutan's biodiversity. Volume 1. World Wildlife Fund. 70 pp.

Zhang, B. L., Dang, F. M. and Li, B. S. (1979). *The farming of musk deer*. Agricultural Publishing Company, Peking. (In Chinese)

Zhang, B. (1983). Musk-deer: their capture, domestication and care according to Chinese experience and methods. *Unasylva* 35: 16-24.

Zheng, S. W. (1980). The feeding and management of young wild musk deer. *The Protection and Use of Wildlife, China* 1: 22-3.

Zheng, S. W. and Pi, N.L. (1979). Research on the ecology of musk deer. *Acta Zoologica Sinica* 25: 176-186. (In Chinese)

ANNEX 1

National distribution of *Moschus* spp. and occurrence within protected areas (*Source:* IUCN/SSC Deer Action Plan, in press)

Afghanistan: *M. chrysogaster* is present in a few parts of Nuristan between 1500m and 3000m where it is considered to be rare (Habibi, 1977).

Protected areas: None

Bhutan: *M. fuscus*, considered by some authorities to be a subspecies of *M. chrysogaster*, occurs throughout much of northern Bhutan, from about 2,600m to the treeline at 4,200m (Green, 1985). It is considered to be rare (Yonzon, 1992) but this may reflect the paucity of survey data.

Protected areas: Black Mountains National Park, Jigme Dorji National Park (IUCN, 1993)

China: The population of *Moschus* in China was estimated to be 600,000 (Sheng, 1987) but the basis of this figure is unclear.

M. berezovskii is the most widely distributed and abundant species of musk deer in China. It occurs in southern Shaanxi, southern Anhui, Jianxi, Hunan, Hubei, Guangdong, Guangxi, Yunnan, Guinzhou, Sichuan, south-eastern Xizang, southern Gansu, south-east Qinghai and southern Ningxia provinces (Wang *et al.*, 1993). Five subspecies are recognised by Wang *et al.* (1993), of which four have contiguous distributions. *M. b. anhuiensis*, previously regarded as a subspecies of *M. moschiferus* (Ohtaishi and Gao, 1990), is isolated from the other races and confined to the Dabie Mountains of western Anhui (Wang *et al.*, 1993).

M. chrysogaster chrysogaster is found in south-eastern Qinghai and southern Tibet. Its distribution abuts that of *M. c. sifanicus*, treated as an independent species *M. sifanicus* by Cai and Feng (1981), which inhabits the eastern edge of the Tibetan Plateau and Meridonial Mountains. In the Pingwu, Markam, Anxian, Beichuan, Litang, Kangding and Muli counties of western Sichuan the distributions of *M. c. sifanicus* and *M. b. berezovskii* overlap, but the former ranges above 3,000m and the latter from 1,000m to 2,500m (Ohtaishi and Gao, 1990). Opinion is unanimous that musk deer populations in Qinghai have declined during the past decade, including Baizha Forest, Nangqian County where densities of 2-3 animals per sq.km were recorded by Harris (1991). According to the Qinghai Provincial Government (1988, cited in Harris, 1991), 66,000 musk deer were illegally harvested in 1985-1986.

M. fuscus, considered by some authorities to be a subspecies of *M. chrysogaster*, occurs in south-eastern Xizang and northern Yunnan (Ohtaishi and Gao, 1990).

M. moschiferus moschiferus is confined to the northern parts of Heilongjiang Province and Inner Mongolia. Its distribution is contiguous with that of *M. m. parvipes* which occurs in Heilongjiang and Jilin provinces (Ohtaishi and Gao, 1990).

Protected areas: Medog, Qomolangma, Tangjiahe, Wanglang and Wolong nature reserves (IUCN, 1993). Changbal Mountain, Helan Mountain, Huaping, Jingpo Lake, Lishan Mountain, Liupen Mountain, Mount Fanjing, Poyang Lake, Shennonglia, Wuling Mountain, Ziyunwanleng Mountain nature reserves (WCMC records).

India: *M. chrysogaster* occurs in parts of Kashmir, Himachal Pradesh, northern Uttar Pradesh, Sikkim and Arunachal Pradesh. Its altitudinal range extends from about 2,400m to above the treeline, which varies from about 3,200m in the Western Himalaya to 4,200m in the Eastern Himalaya. The species is likely to be most numerous in the eastern Himalaya where its habitat has been least disturbed. Further details of its status are given by Green (1985). Fewer than 1 animal per sq.km recorded in Kashmir, and 5-6 per sq.km in Kedarnath Sanctuary, Uttar Pradesh (Green, 1985, 1987).

M. fuscus, considered by some authorities to be a subspecies of *M. chrysogaster*, occurs in Assam and Sikkim.

Protected areas: Recorded in over 20 Himalayan national parks and sanctuaries (IUCN, 1993).

Korea: *M. moschiferus parvipes* is considered to be in danger of becoming extinct (Won, 1988). It occurs in the wooded, mountainous parts of the Korean peninsular, but information on its present distribution is lacking.

Protected areas: No information

Mongolia: *M. moschiferus* is found in the taiga of Hentei and Hovsgol, parts of Hangai and possibly in the Han Hohii massif in the north-west. It is uncommon due to hunting for musk (Mallon, 1985).

Protected areas: Likely to occur in Khorgo Reserve (Hangai); Ar-Toul and Gorkhi-Terelj national parks, and Bogdkhan Uul and Khan Khentii Uul reserves (Hentei); and Khovsgul Nuuer National Park (Hovsgol).

Myanmar: *M. fuscus*, considered by some authorities to be a subspecies of *M. chrysogaster*, occurs only in Kachin State of northern Myanmar. In the hills around Putao it is generally found above 2,400m.

Protected areas: None

Nepal: *M. chrysogaster* is widely but discontinuously distributed throughout the Himalaya from about 3,000m to 4,400m (Green, 1985). The population is thought to be increasing within protected areas but declining outside them. Sagarmatha National Park has an estimated 600-800 animals, with up to 45 per sq. km. Elsewhere, there are an estimated 500 animals in Langtang National Park, 20 in Rara National Park and >1000 in Shey-Phoksundo National Park (B. Kattel, pers. comm., 1990).

M. fuscus, considered by some authorities to be a subspecies of *M. chrysogaster*, occurs in the Everest region.

Protected areas: As above. Also present in Dhorpatan Hunting Reserve, Khaptad National Park and Makalu-Barun National Park/Conservation Area (IUCN, 1993).

Pakistan: *M. chrysogaster* is widespread from 3000m to 4000m in the Northern Areas, but has become rare in Chitral and the Indus Kohistan, North-West Frontier Province. It has never been as plentiful in the north-western Himalaya as further east where it inhabits lower altitudes due to the higher rainfall (Roberts, 1977).

Protected areas: Astore, Baltistan, Kargah, Manshi, Nar/Ghoro Nallah, Satpara wildlife sanctuaries (IUCN, 1993)

former USSR: Of the three subspecies of *M. moschiferus*: *M. m. moschiferus* is widely distributed throughout eastern Siberia, from the Altai Mountains in the west to the Kolymskiy Mountains in the east; *M. m. parvipes* occurs in the Ussurisk region of eastern Russia (Whitehead, 1994); and *M. m. sachalinensis* is restricted to four populations in the southern half of Sakhalin Island (V.E. Prisjazhnyuk, pers. comm., 1994). The species does not occur above 1,600m in the former USSR. Bannikov *et al.* (1980) estimated the total population in the former USSR to be approximately 100,000, based on a mean density of 0.6 animals per sq.km (densities rise to 20 animals per sq.km in optimal habitats). Population is declining, following the disintegration of the former USSR, and currently estimated to total 56,000-60,000, with 29,000-30,000 in the Altai and Sajany, 18,000-19,000 around Lake Baikal, 5,000-6,000 in Siberia, 4,000-5,000 in the Far East and 300-350 on Sakhalin Island (V.I. Prikhod'ko, pers. comm., 1994). In Khabarovsk Krai (Far East), there were an estimated 18,000 musk deer in 1994 according to Khabarovsk Game Department.

Protected areas: Occurs in a total of 1 national park, 21 zapovedniks and 5 other protected areas (V.I. Prikhod'ko, pers. comm., 1994). In Russia, present in Komsomolskiy, Sikhote-Alinskiy, Ussyriryskiy and Zeyskiy zapovedniks (Golovanov, 1985; G. Gonzalez, 1994) and Altaiskiy, Baikal'skiy, Barguzinskiy and Bol'shekhekhtsizskiy zapovedniks (WCMC records).

Vietnam: *M. berezovskii* occurs in Lang Son and Cao Bang provinces of north-eastern Vietnam. There are an estimated 200-300 in Cao Bang Province but the population is decreasing (H.H. Dang, T. van Dao and M.K. Hoang, pers. comm. 1990).

Protected areas: Trung Khanh Nature Reserve (H.H. Dang, T. van Dao and M.K. Hoang, pers. comm. 1990)

ANNEX 2

Summary of national legal provisions for musk deer (Source: IUCN/SSC Deer Action Plan, in press)

Afghanistan: No legal protection or other conservation action.

Bhutan: Totally protected by Royal Decree.

China: Protected as a Category II *key* species under the federal *Wildlife Protection Law, 1988.* Category II species may be taken only under permit granted by the provincial authority. Qinghai Provincial Government has promulgated a special *emergency notice*, under its *Wildlife Resources Protection and Management Regulations, 1988*, to draw attention to the plight of the musk deer and to strengthen its protection. However, there is no evidence to suggest that legal protection has been effective (Harris, 1991).

Efforts to establish an effective network of nature reserves to conserve the Giant Panda have indirectly benefitted *M. berezovskii* which occurs in similar habitat.

India: Totally protected under the federal *Wildlife (Protection) Act, 1972.*

Korea: Protected since 1968 when it was designated as Natural Monument No. 216. A Musk Deer Preservation Council was established in 1978 under the auspices of the Korean Wildlife Preservation Association. No recent information.

Mongolia: Totally protected as an endangered species under new legislation introduced on 5 June 1995.

Myanmar: Totally protected under the *Nature and Wildlife Law, 1994.*

Nepal: Totally protected under the *National Parks & Wildlife Conservation Act, 1973.*

Pakistan: No legal protection or other conservation action at national level.

former USSR: In the Russian Federation, musk deer are hunted under licence but regulations vary between krais. For example, in Khabarovsk Krai the legal harvest quota in 1994 was 2,000, whereas in Krasnojarski Krai hunting has been prohibited since 1994 (G. Schürholz, pers. comm.). In Sikhote-Alinskiy Zapovednik the legal annual harvest is 70 musk deer (Gonzalez, 1994). It is planned to establish a zapovednik by 2000 for the protection of *M. m. sachalinensis* on Sakhalin Island (V.E. Prisjazhnyuk, pers. comm., 1994).

Vietnam: Protected under national legislation since 1963.